Report on:

Home Ventilation

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So they took soot from a furnace and stood before Pharaoh. Moses tossed it into the air, and festering boils broke out on people and animals.

- Exodus 9:10

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Abstract

The purpose of this document is to describe the indoor ventilation requirements for Habitat for Humanity homes and inform about applicable mechanical ventilation solutions.

It was determined that an average Habitat house needs approximately 40.5 cubic feet per minute of fresh air entering the house. The results from a blower-door test, which is designed to show how leaky a house is, can be used to find the amount of fresh air naturally entering the house. If that natural level of infiltrating air is less than 40.5 cubic feet per minute, some type of mechanical ventilation is necessary.

This requirement can be met via either using bathroom and kitchen exhaust fans or by installing a Energy Recovery Ventilator unit in line with the heat & air unit. Although each of these solutions have different costs and benefits, no matter what solution is used, there are significant benefits to the homeowner including less allergy symptoms, better long-term health, and reduced pollution damage which increases durability of the house.

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Introduction

Habitat houses are being built with better windows, better doors, thicker insulation, home wrap, and many other techniques to seal the house to prevent energy loss to the outside. Although this significantly reduces the amount of energy required to heat and cool the house, it also has a negative effect of reducing the amount of fresh air leaking into the house. This lack of fresh air and ventilation has caused an increased concern for the health and safety of the occupants.

This is hard to quantify without significant research and calculations, and thus the task was given to me to determine whether or not new Habitat homes need some type of added ventilation system. With my research and report, Habitat will be able to make more informed decisions when it comes to ventilation in future builds.

First I will explain the objectives of the project and how I approached it. Then I will explain the ventilation requirements from ASHRAE. Then I will explain the blower door test and how that can be used to determine the level of natural (or leaking) ventilation into the house.

Also, many of the numbers in this paper are approximations and are not meant to be very precise, especially given varying weather conditions, different houses, and many other factors. The formulas presented in this paper should be taken rather as educated rules-of-thumb.

Objectives

The objectives of this project are to:

1. Determine the recommended level of ventilation for a standard Habitat house in Arkansas according to reliable sources.
2. Develop a way to determine how much natural ventilation is entering a house
3. With the above information, develop a method to decide whether or not a home needs a mechanical ventilation system and what type is best.
4. Select a few feasible ventilation solutions and gather important information on them regarding their cost and benefits to both Habitat for Humanity and the homeowner.

Definitions

Several acronyms will be used throughout this paper. Refer to this section to find the meaning of an acronym.

ACH – Air Exchanges per Hour
ASHRAE – American Society of Heating Refrigeration and Air-conditioning Engineers
CFM (sometimes cfm) – Cubic Feet per Minute
HVAC – Heating Ventilation and Air Conditioning

Findings

Although few studies have been done about the health benefits of good ventilation, the data that is available shows that better ventilation reduces symptoms of allergies and asthma significantly.

There are many types of indoor pollutions such as pesticides, Radon, Formaldehyde, and smoke that can cause harm to humans. The Environmental Protection Agency (EPA) cautions homeowners to be aware of these dangers. Radon can be deadly when in high concentrations, and since the level of Radon varies significantly from home to home based on location and other factors, the EPA recommends getting an official inspection to measure the Radon level in a home. Although Arkansas is not a high-risk area for Radon, harmful amounts of the element may be present. Many pressed wood products, carpets, and other building materials contain chemicals that can be harmful to a person especially for long periods of time without adequate fresh air. It is imperative that Habitat homeowners be aware of indoor pollution sources in their new home and how to deal with them.

There are two main categories of requirements regarding ventilation that are important to be aware of: local ventilation and whole-house ventilation. Local ventilation involves removing air or diluting air from local pollution sources such as bathrooms, basements, garages, and ranges. Whole-house ventilation refers to the amount of fresh air coming to the entire house.

Local Ventilation Requirements

ASHRAE, the American Society of Heating Ventilation and Air-conditioning Engineers, publishes standards with recommendations and regulations regarding HVAC systems. ASHRAE

62.2 is entitled 'Ventilation and Acceptable Indoor Air Quality in Low-Rise Residential Buildings' and is the go-to reliable source for this topic.

EnergyStar is a joint program of the U.S. Environmental Protection Agency (EPA) and the U.S. Department of Energy set up to encourage environmentally friendly living through energy efficient products and practices.

ASHRAE 62.2 and EnergyStar both regulate the local exhaust for Kitchens and Bathrooms.

ASHRAE 62.2 5.1 (2010) says:

"A local mechanical exhaust system shall be installed in each kitchen and bathroom. Each local ventilation system shall be either one of the following two:

a. an intermittent mechanical exhaust system meeting the requirements of Section 5.2 or
b. a continuous mechanical exhaust system meeting the requirements of Section 5.3"

The following tables are directly from ASHRAE 62.2, Sections 5.2 and 5.3 respectively.

TABLE 5.1 Intermittent Local Ventilation Exhaust Airflow Rates

Application	Airflow	Notes
Kitchen	100 cfm (50 L/s)	Vented range hood (including appliance-range hood combinations) required if exhaust fan flow rate is less than 5 kitchen ach.
Bathroom	50 cfm (25 L/s)	

Figure 1

TABLE 5.2
Continuous Local Ventilation Exhaust Airflow Rates

Application	Airflow	Notes
Kitchen	5 ach	Based on kitchen volume.
Bathroom	20 cfm (10 L/s)	

Figure 2

Converting from ACH to cfm is simple once we have the volume of the kitchen. We will assume:

$$Volume_{kitchen} = (12)(14)(7.5) = 1260\ ft^3$$

Now, calculating the ACH from the cfm is easy as:

$$ACH = \frac{(cfm) * (60)}{volume_{kitchen}}$$

And finding cfm from the ACH is:

$$cfm = \frac{ACH * Volume_{kitchen}}{(60)}$$

Whole-house ventilation Requirements

ASHRAE also has specific requirements for whole-house ventilation as well. The 2010 version of ASHRAE 62.2 gives the following formula for calculating the necessary volume flow rate of fresh air entering the entire house.

$$Q_{fan} = (0.01)A_{floor} + 7.5(N_{bedrooms} + 1)$$

where:

Q_{fan} = required volumetric flow rate of fresh air in cfm $\left(\frac{ft^2}{min}\right)$
A_{floor} = Area of the floor in ft^2
$N_{bedrooms}$ = number of occupied bedrooms

Plugging in the numbers specific to a typical White County Habitat home:

Area = 1050 square feet
Floor to ceiling height = 7.5 feet
Numbers of bedrooms = 3

$$Q_{fan} = (0.01)(1050ft^2) + 7.5ft(4)$$

$$Q_{fan} = 40.5\ cfm$$

Blower Door Test

The blower door test is an objective test that essentially measures how leaky the house is, which is important for energy efficiency calculations. The test is performed by closing all windows and doors and putting a special fan in one door. The fan is turned on to create a pressure difference of 50 Pascals between inside the house and out. The result of the blower door test is a number measured in units of CFM50, meaning Cubic Feet per Minute at 50 Pascals pressure difference. The lower the number the tighter the house, and conversely, the higher the CFM50, the leakier the house. A house is tight if its ACH50 is less than 6 or so and leaky houses can have an ACH50 of 20 or more. Although the number doesn't have much reference frame, and a cfm50 of 4.9 might not say much to an average person, this number can be used to find how much air is leaking into the house under normal conditions.

Figure 3 (Blower Door)

We will convert the CFM50 to ACH50 for calculation purposes. (which some blower door units can do automatically)

$$ACH_{50} = \frac{(cfm_{50}) * (60)}{volume_{house}}$$

The ACH50 is directly related to the AHC of fresh air leaking into the house under natural conditions according to the following formula:

$$ACH_{natural} = \frac{ACH_{50}}{LBL\ Factor}$$

NOTE: $ACH_{natural}$ is also sometimes referred to as NL for natural leakage.

The LBL factor is a constant that depends on your climate region as well as the size of the number of stories of the house. The default number for less precise calculations is 20. EnergyStar published a report in 2001 on Home Sealing Specifications which explains how a more accurate LBL factor can be determined based on the climate zone, number of stories, and how well the house is shielded. This information is included in Appendix B. For a 1-story house in Arkansas, under normal wind exposure conditions, the LBL factor is given as 21.5 giving us:

$$ACH_{natural} = \frac{ACH_{50}}{21.5}$$

The natural CFM can be found from the natural ACH using the volume of the house according to the following formula:

$$cfm = \frac{ACH * Volume_{house}}{(60)}$$

We will assume:

$$Volume_{house} = (square\ footage)(ceiling\ height)$$

$$Volume_{house} = (1050\ ft^2)(7.5\ ft)$$

$$Volume_{house} = 7875\ ft^3\ \approx 7000\ ft^3$$

The volume was rounded down to 7000 cubic feet as a simple approximate way to account for interior walls, furniture, and uncirculating storage space.

Plugging this into our formula for cfm, we get,

$$cfm_{nat} = \frac{ACH_{50} * 7000}{21.5 * 60} = 5.426\ ACH_{50}$$

Graphing this formula gives us the blue line on the figure below.

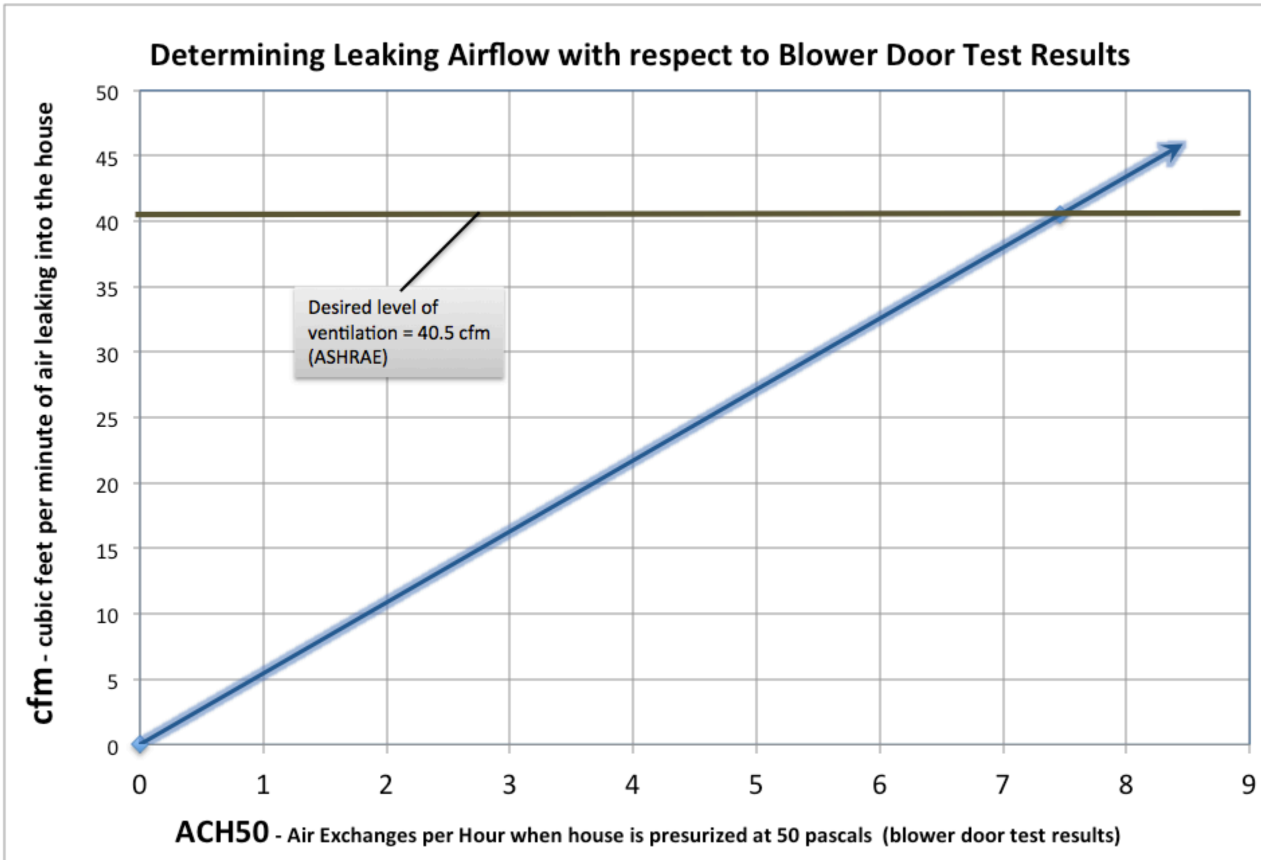


Figure 4.

The brown line shows the level of ventilation required by ASHRAE 62.2.

The blue line represents the relationship between the blower door test result and the natural flow rate of fresh into the house.

Determining a Solution

With this information, the type of ventilation solution that is needed can now be determined.

If the blower door test gives a result less than approximately 7.5 then, according to the figure 1, there is not enough natural ventilation to provide adequate ventilation for the house. The next step is determining how much mechanical ventilation system is needed. Using figure 1 and the blower door test result, find the natural cfm of the house. Subtracting this number from 40.5 gives us the number of cfm's of mechanical ventilation needed.

There are several types of solutions available of which two are feasible.

Solutions: Local Exhaust Fans

This option uses the required bathroom and kitchen exhaust fans to provide the necessary ventilation to the entire house. It is the simplest solution and has the lowest up-front cost.

Given that the volume of the kitchen and bathroom are each approximately 14ft x 12ft, the volume of each room is:

$$Volume_{kit/bath} = (12)(14)(7.5) = \ 1260\ ft^3$$

If continuous local ventilation fans are used:

$$cfm_{kitchen} = \frac{ACH_{kitchen} * 1260}{(60)} = 105\ cfm$$

and

$$cfm_{bath} = 20\ cfm$$

Thus the total exhaust ventilation of the house would be 125 cfm, which sufficiently meets the 40.5 cfm requirement.

Using intermittent local ventilation fans gives us:

$$cfm_{total} = cfm_{bath} + \ cfm_{kitchen} = 50 + 100 = 150 cfm$$

Dividing the required ventilation by this, we get:

$$\frac{40.5 cfm}{150\ cfm} = 0.27$$

Thus the fans would have to be running 27% of the time in order to provide adequate ventilation.

This solution also has many drawbacks that must be considered:

- Motor Inefficiency. Exhaust fans generally have loud and inefficient motors. Although EnergyStar has requirements on how quiet and efficient they must be, these fans are far from perfect.
- Control. It requires significant human intervention or automated control system. Occupants generally are not a reliable method of controlling when the fans, thus it is

advised to install an additional control system that will cycle the fans on and off throughout the day, keeping the fans running the needed 27% of the time.

- Negative Pressure. Using any type of exhaust-only ventilation system creates a negative pressure on the building, which is considered undesirable. For this reason, the option of a whole-house exhaust system was eliminated. That type of design would cost more and than the kitchen/bathroom solution and would have the same problems. The exhaust-only system implies that the air is still coming in through cracks and leaks in the house. This means that if the house is properly built, the house will actually not get the 40.5 cfm of required fresh air, and instead the house will build a significant negative pressure. The exhaust-only method also makes the house more leaky over time by drawing air in through leaks and cracks.
- Thermal Ineffiency. It creates added work for the heat & air unit by expelling air that is the desired temperature of the room and draws air in through leaks in the building that is the temperature of the outside air. In the winter-time this effectively dumping warm air outside and pulling cold air inside, thus making the heater run more to heat the fresh air.

Solutions: Energy Recovery Ventilator

The other solution is the Energy Recovery Ventilator (ERV). Although this option is more expensive, it is by far the best. This solution is recommended by HVAC engineers and technicians worldwide. The unit has ducts that lead to the heat & air unit as well as ducts that lead to the outside. It provides the house with fresh air at any desired rate, and can be connected to trigger on and off with the heat & air unit.

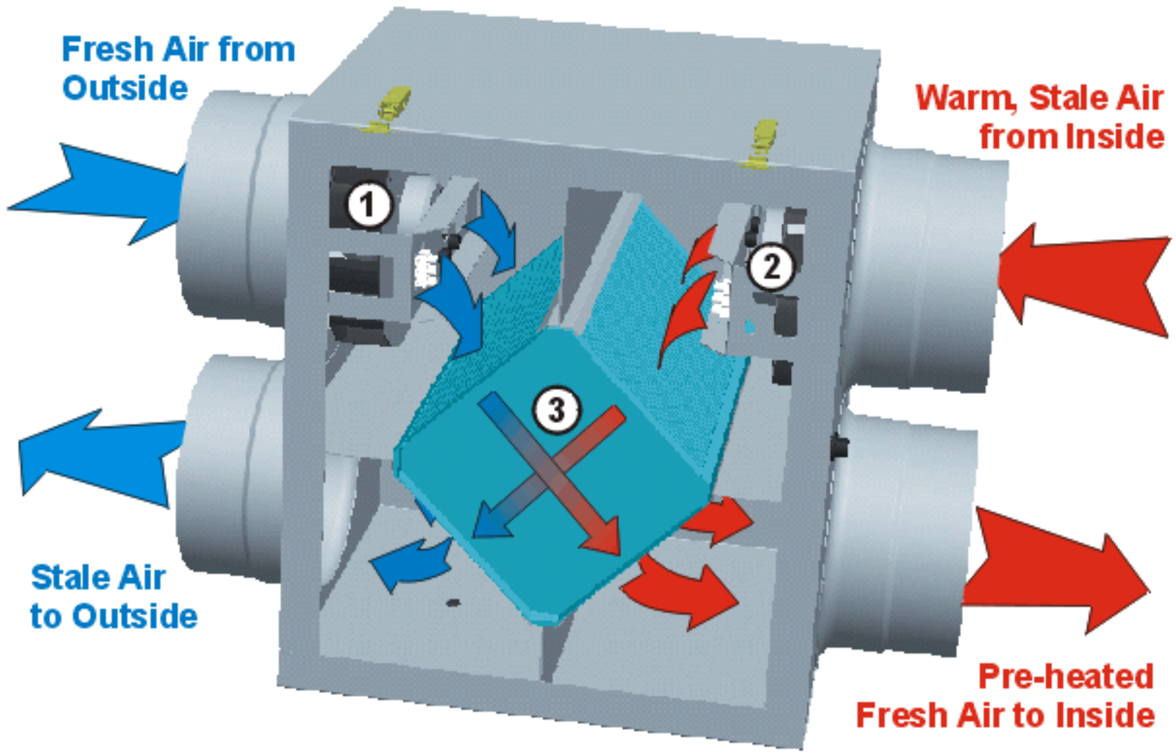


Figure 5 (ERV in winter)

The teal colored box in the middle represents the special filter which transfers heat from the stale air to the cold air that is coming in. This gives the effect of heating the air that is coming into the house. The incoming air is now almost room temperature.

Benefits

Although the ERV is considered the gold standard among residential indoor ventilation solutions for several main reasons:

- Control. Most ERV models have an automated control unit thus eliminating the need for the residents to turn on or off the ventilation system.
- Heat & and Air integration. The ERV can be installed such that the fresh air air from the ERV goes directly into the heat & air unit. Their control systems can also be integrated such that when the heat and air unit cycles on or off, the ERV does as well, making the whole system even more efficient.
- Efficiency. Because the incoming fresh air is warmed (in winter) by the exiting stale air the fresh air doesn't require the heat & air unit to heat the air as much to get it to the desired room temperature. This makes the ERV significantly more energy efficient than the bathroom / kitchen exhaust ventilation system.

- Availability. Units such as the Trane FreshEffects or the Broan ERV90 are widely available from heat & air contractors around the country. This solution is especially recommended for a climate like Arkansas where the humidity is high.

Drawbacks

- Cost. The only major drawback to the ERV system is its pricetag. The cost for the whole system, including installation, even for a small home is most likely significantly over $1000.

Solutions: Other less feasible solutions

As with any project, several solutions had to be eliminated in order to chose these two.

- Central fan unit. Similar to the bathroom/kitchen exhaust fan system, this works by expelling air out of the house. This system requires an additional fan and additional ductwork to allow airflow to all the rooms, which is an added cost. Generally these fans are more efficient than a bathroom fan, thus reducing the energy costs consumption slightly. Although this method provides better circulation, it still has the same drawbacks as the exhaust fan method: thermal inefficiency, negative pressure, and control.
- Balanced Central Fan. This solution is identical to the above except it provides a balanced pressure by running additional ductwork and possibly an additional fan. This adds cost and also sometimes creates uncomfortable drafts in the home.

Homeowner Benefits:

By installing a ventilation system, the homeowner will receive the following benefits:

HEALTH: Immediate health risks associated with indoor air pollution such as asthma and flu will be reduced. Good air quality also reduces the risk of heart and lung diseases and cancer caused by pollution such as Radon, VOC's, fuel, and building materials.

SUSTAINABILITY: ERV systems recover energy from exiting air, thus reducing the energy consumption and cost.

COST: Each of the two viable solutions has different initial and operating costs.

DURABILITY: Fresh air reduces the risk of humidity, mold, smoke, and other pollution damage to the house.

Conclusions

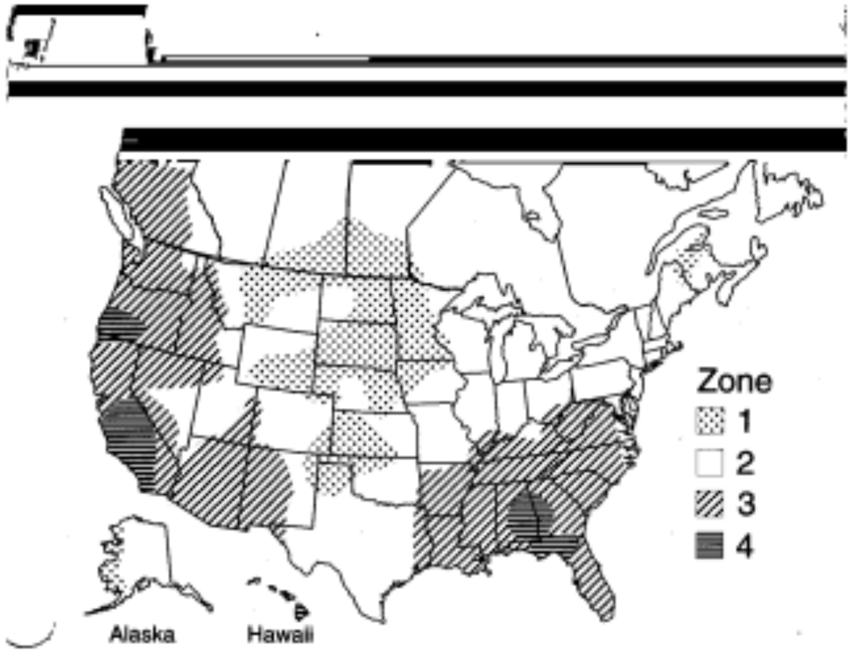
To sum things up:

- ASHRAE and EnergyStar require bathroom and kitchen ventilation
- ASHRAE recommends 40.5 cfm of incoming fresh air for a house matching typical white county Habitat builds
- A blower door test can be done to estimate how much fresh air is coming into the house and how much mechanical ventilation is needed using the formulas and figures found above.
- Two good solutions are available, the bathroom/kitchen exhaust vent system, and the Energy Recovery Ventilator system both providing adequate ventilation, but each with their own drawbacks.

REFERENCES

- EnergyStar website. www.energystar.gov
- ASHRAE website. www.ashrae.org
- EPA website. www.epa.gov
- The official EngergyStar checklist. http://www.energystar.gov/ia/partners/bldrs_lenders_raters/downloads/InspectionChecklists.pdf
- Information on the Trane FreshEffects ERV unit. http://www.trane.com/Residential/Products/air-filtration/FreshEffects-Air-Filtration
- Link to view or buy the ASHRAE standards including 62.2. http://www.ashrae.org/technology/page/548
- Lawrence Berkeley Laboratory Indoor Air Quality Scientific Findings Resource Bank. http://eetd.lbl.gov/ied/sfrb/sfrb.html
- Lawrence Berkeley Laboratory report on The Use of Blower-Door Data. http://epb.lbl.gov/blowerdoor/docs/BlowerDoor.pdf

APPENDIX A: Chart and map for determining the LBL factor.



Zone	# of stories ➜	1	1.5	2	3
1	Well-shielded	18.6	16.7	14.9	13.0
	Normal	15.5	14.0	12.4	10.9
	Exposed	14.0	12.6	11.2	9.8
2	Well-shielded	22.2	20.0	17.8	15.5
	Normal	18.5	16.7	14.8	13.0
	Exposed	16.7	15.0	13.3	11.7
3	Well-shielded	25.8	23.2	20.6	18.1
	Normal	21.5	19.4	17.2	15.1
	Exposed	19.4	17.4	15.5	13.5
4	Well-shielded	29.4	26.5	23.5	20.6
	Normal	24.5	22.1	19.6	17.2
	Exposed	22.1	19.8	17.6	15.4

$$ACH_{nat} = \frac{ACH_{50}}{LBL\ Factor}$$